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US ARMY MEDICAL RESEARCH LABORATORY

FORT KNOX, KENTUCKY

REPORT NO. 685

CHARACTERISTIC PACE AS DETERMINED BY
THE USE OF A TRACKING TREADMILL

by

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and

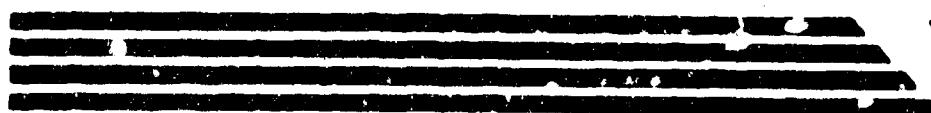
George S. Harker, Ph. D.

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THE USE OF A TRACKING TREADMILL

by

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and
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Fort Knox, Kentucky 40121

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Biomechanical Aspects of Performance and Performance Decrement
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ABSTRACT

CHARACTERISTIC PACE AS DETERMINED BY
THE USE OF A TRACKING TREADMILL

OBJECTIVE

To measure individuals' walking behavior on a tracking treadmill on three testing days to determine: (1) if individuals demonstrate a characteristic pace walking under a "comfortable-but-determined" (C-D) instructional set; and (2) if individuals' characteristic C-D pace is stable over time.

RESULTS

(1) Individuals demonstrate a characteristic pace that is stable on a given day. (2) Individuals differ statistically in their characteristic pace. (3) Characteristic C-D pace measures are most reliable between testing days 2 and 3.

IMPLICATIONS

Utilize characteristic pace measures obtained under a C-D instructional set, to investigate the application of relative or proportional loading to the dynamic muscle group responses involved in walking in the study of strength and endurance.

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CHARACTERISTIC PACE AS DETERMINED BY THE USE OF A TRACKING TREADMILL

INTRODUCTION

A growing interest in and understanding of various modes of muscle activity has recently been experienced. The study of the characteristics of limb activity has been expanded to include: (1) the endurance of the leg as a function of the force applied to a pedal (5); (2) the relationship between initial maximum grip strength and strength-endurance for a fixed period of time (12); (3) the response endurance of different muscle groups at various fractions of the maximum response strength (10); (4) the temporal components of motion in human gait (11); (5) the multidimensional force components of "normal" and hemiplegic gait (1); (6) the force components of deep knee bends (9); and (7) the proportionate relationship of the sustained grip force to the maximum strength of the response as an index of working efficiency and recovery functions for various relative loads (4).

There have been two exciting innovations in the above mentioned research. The first being Barany's (1, 2) construction of a force-platform suitable for measuring the bodily forces exerted by hemiplegic patients while walking on a treadmill and the subsequent development of a data reduction system which accurately integrates the resulting force traces over time with respect to amplitude and direction (frontal, lateral and vertical). The second innovation is found in Caldwell's research (3, 4) in which he has refined a technique employing relative-loading which resulted in the demonstration that differences in grip endurance were unrelated to differences in strength.

The prior treadmill research conducted in this laboratory by Evans (6, 7), who developed a technique utilizing a titration schedule to measure performance decrement as a function of continuing heavy muscular exertion, and Caldwell's research utilizing a static manual response led to the idea that the treadmill could conceivably be utilized to investigate the application of the "relative or proportional loading" technique to the dynamic muscle group responses involved in walking.

Before relative loading can be applied to pace, a valid and reliable point of reference must initially be determined (e. g., analogous to Caldwell's maximum grip strength). Initially, it was felt that the point at which S broke into a run would yield such a measure. Several pilot studies, however, suggested that such a measure may be lacking in the

necessary validity and reliability for a variety of reasons: (1) the effect of the treadmill task just preceding the maximum walk measure was a confounding factor; and (2) the particular instructions given the Ss were found to influence the maximum walking rate, and among other problems, the treadmill maximum speed of 6.5 mph did not exceed the speed of the fastest walker.

In view of the above it was determined to evaluate the Ss' "comfortable-but-determined" walk in the hope that a valid and reliable "characteristic" pace might be obtained. If it could be demonstrated that Ss have a stable "characteristic" pace, then it would be possible to increase or decrease the pace by a percentage to study various measures of strength and endurance.

The purposes, therefore, of the present research were to determine: (1) if individuals have a characteristic pace; and (2) if the pace is stable over time.

METHODS AND PROCEDURES

Apparatus

The apparatus (Fig. 1) was essentially that described by Evans (7), with a few modifications. The variable speed (1.5 mph to 6.5 mph) treadmill was set at a 0.0% grade. The speed control of the treadmill, which in the usual application is manually set to a fixed speed for a run, was connected by an appropriate mechanical coupling to a reversible electric motor. In one direction of rotation, this motor drove the speed control of the treadmill to produce a constant acceleration of the treadmill. In the other direction of rotation, the speed control produced a constant deceleration. The speed control motor was set to produce an acceleration or deceleration of the treadmill of two feet per min. per sec.

In the Evans (7) study the direction of rotation of the speed control drive was determined by a spring loaded switch held by S as he walked on the treadmill. When S depressed the switch, the treadmill decelerated; when S released the switch, the treadmill accelerated. This arrangement required that S continuously make overt responses to the acceleration or deceleration of the treadmill to produce the titration schedule. Under these conditions an S instructed to walk at a "comfortable-but-determined" pace would establish his "steady" pace by constantly accelerating or decelerating the treadmill to produce a sinusoidal envelope of treadmill speeds.



Fig. 1. Tracking treadmill, modification of Quinton Instrument Company model 18-60.

In the present study it was desired that the treadmill speed "track" the S's pace as he walked on the treadmill. This was achieved by the use of a three position, spring loaded switch actuated from a belt clip attached to S (Fig. 1, above). The system was so designed that, if S walked at a designated location on the treadmill, the switch would be in the neutral (number 2) position, and the acceleration-deceleration (A-D) drive would not be activated, so the treadmill would run at a constant speed. If, however, S increased his pace (either length of stride or steps per minute) since he would move forward on the mill, the switch would be pulled to the accelerate (number 1) position, and the A-D drive would accelerate the treadmill to match speed with S, at which time the walker would again be at the neutral location on the treadmill, allowing the switch to drop into the constant velocity position. Conversely, if S decreased his pace, he would simultaneously move backward on the treadmill, the switch would drop to the decelerate (number 3) position, and the A-D drive would decelerate the treadmill until its speed matched that of S's pace. Ear phones with muffs and a low level (10 db) white noise were employed to mask the

noise of the activated A-D drive to insure that the primary cues to walking pace would be of a proprioceptive mode. To further control extraneous cues, S was instructed to look straight ahead, and the manual speed change handle on the side of the treadmill was covered, as was the front edge of the treadmill belt.

A continuous tracing of treadmill speed obtained from a tachometer-generator attached to the treadmill drive was recorded graphically with a Moseley Model 680 strip chart recorder.

The advantages of the above procedures are: (1) the S is not forced to respond to the continual acceleration-deceleration implicit in the titration schedule approach; (2) the speed track of the treadmill should be narrower, more closely following the natural accelerations and decelerations of normal walking; and (3) extraneous cues which might influence the walking pace are minimized.

Subjects

Nineteen male Ss who had just completed six months basic training were employed in this investigation. The Ss, whose average age was 19.7 years, wore regulation fatigue pants, tee shirt and combat boots (average weight 5.5 lbs). Walking was performed in a temperature controlled chamber at 80°F.

Procedure

During the week prior to the data taking sessions, each S walked for 30 min on the treadmill for familiarization. The purpose of the familiarization was to allow the Ss to become adapted to walking on the treadmill and to become adjusted to the accelerating and decelerating of the treadmill as it matched their pace.

The task for all Ss on each of the three days of testing was as follows: (1) two short walks starting from either a fast walk (5 mph) or a slow walk (2 mph) during which the Ss either decelerated or accelerated their pace to reach their "comfortable-but-determined" (C-D) walking pace; (2) a 30 min walk at their C-D pace; and (3) two short walks again starting from either a fast or a slow walk to adjust their pace to reach their C-D pace. For Group I the short pre- and post-walk (fast start then slow start or slow start then fast start) was randomly determined, and the walk lasted 4 min. For Group II the pre- and post-walking conditions were randomized, but the walk lasted 8 min. The present concern is with only the 30 min walk.

The instructional set for the C-D pace was determined by the instructions "walk as though you were going from here to the theater (.5 mile) and had just time enough to get there before the start of the feature without pushing yourself too hard." There was a 5 min rest between each condition. The session for each of the three testing days was 66 min for Ss in Group I and 86 min for Ss in Group II.

RESULTS AND DISCUSSION

In an effort to learn if Ss revealed a characteristic pace during their 30 min walk and if this pace was stable over time, two analyses of variance were computed (Tables 1 and 2).

TABLE 1

SUMMARY TABLE OF ANALYSIS OF VARIANCE OF THE FIRST 15 MIN VS. THE LAST 15 MIN OF THE C-D WALK. GROUP I.

EMS	Source	SS	df	MS	F	P
AxC	A Days	5.3287	2	2.6644	1.3989	n.s.
BxC	B Conditions	.1285	1	.1285	.8718	n.s.
Within	C Subjects	126.1903	8	15.7738	1421.0631	<0.001
AxBxC	AxB	.0892	2	.0446	.4811	n.s.
Within	AxC	30.4755	16	1.9047	171.5946	<0.001
Within	BxC	1.1793	8	.1474	13.2793	<0.001
Within	AxBxC	1.4830	16	.0927	8.3514	<0.001
Within		8.4173	756	.0111		
	Total	173.2918	809			

TABLE 2
SUMMARY TABLE OF ANALYSIS OF VARIANCE OF THE FIRST 15 MIN
VS. THE LAST 15 MIN OF THE C-D WALK. GROUP II.

EMS	Source	SS	df	MS	F	P
AxC	A Days	3.7951	2	1.8976	.4022	n. s.
BxC	B Conditions	.0205	1	.0205	.0414	n. s.
Within	C Subjects	193.4261	9	21.4918	820.2977	<0.001
AxBxC	AxB	.8248	2	.4124	1.5451	n. s.
Within	AxC	84.9162	18	4.7176	180.0611	<0.001
Within	BxC	4.4587	9	.4954	18.9084	<0.001
Within	AxBxC	4.8043	18	.2669	10.1870	<0.001
	Within	21.9907	840	.0262		
	Total	314.2364	899			

The analyses reveal that the main effect conditions (first 15 min vs. last 15 min of the 30 min walk) were not significant, suggesting that for each group the C-D pace an S adopted was relatively stable. The Ss main effect was found to be highly significant ($P < 0.001$) as was the Ss by days interaction. These findings reveal that Ss' paces differ from each other and suggest that though an S's pace was stable for any one day, his pace may differ from day to day. These observations contribute to accounting for the fact that both the conditions by Ss and the days by conditions by Ss interactions were statistically significant. No systematic day to day variation in Ss' paces (such as a continual increase or decrease in pace) was observed as evidenced by the fact that neither the main effect days nor the days by conditions interaction were statistically significant.

In an effort to determine what relationships did exist among the three days of testing a series of Pearson product moment correlations were computed.

The average mph for the 30 min walk was computed for each S. Means and standard deviations for Ss in both groups are presented in

Table 3. Justification for averaging across the 30 min is taken from the observation that the conditions main effect was not statistically significant. The mean mph for an S is therefore a measure of his C-D pace and was used to compute the correlations between days (Table 3).

TABLE 3
MEANS AND STANDARD DEVIATIONS FOR EACH S's 30 MIN C-D WALK FOR DAYS 1, 2, 3, AND AVERAGE DAYS 1-3 IN MPH

Subject	Days	Means				Standard Deviations			
		1	2	3	1-3	1	2	3	1-3
Group I	1	2.72	2.40	2.15	2.42	.142	.118	.152	.270
	2	3.17	3.17	3.00	3.11	.122	.113	.069	.133
	3	3.04	2.65	2.95	2.88	.063	.128	.078	.194
	4	3.03	3.83	3.46	3.44	.082	.136	.103	.343
	5	3.16	3.34	3.47	3.32	.089	.086	.118	.160
	6	2.96	2.15	2.33	2.48	.120	.178	.091	.375
	7	3.34	3.00	2.88	3.07	.113	.116	.138	.231
	8	3.52	3.35	3.20	3.36	.079	.111	.237	.204
	9	3.76	3.62	3.53	3.63	.070	.075	.114	.131
	\bar{X}	3.19	3.05	3.00	3.08	.098	.118	.122	.227
Group II	1	3.94	4.02	3.87	.394	.202	.045	.135	.157
	2	3.77	3.78	3.98	3.85	.069	.114	.135	.145
	3	3.61	2.83	2.84	3.09	.414	.184	.176	.452
	4	3.88	3.79	3.91	3.86	.174	.083	.219	.177
	5	3.79	3.74	3.88	3.81	.335	.110	.098	.218
	6	2.83	2.97	3.23	3.01	.173	.135	.138	.232
	7	3.79	3.87	3.79	3.82	.185	.100	.230	.183
	8	2.56	2.23	3.06	2.62	.270	.275	.115	.413
	9	2.95	4.17	4.54	3.89	.241	.107	.173	.701
	10	3.75	2.80	2.68	3.08	.284	.124	.138	.518
	\bar{X}	3.49	3.42	3.58	3.50	.236	.128	.156	.319

Inspection of Tables 4 and 5 reveals that for both groups the C-D pace was more reliable between Days 2 and 3 than between any other two-day combinations ($P < 0.01$). The analyses up to this point indicate that performance in each of the two groups was comparable with the exception that examination of Table 3 shows that the average mph for

Group I was .42 mph lower than Group II. An even more interesting difference, however, is revealed by the fact that the correlation between Days 1 and 3 for Group I was significant beyond the .05 level of significance (Table 4), but for Group II the comparable correlation did not even approach significance (Table 5).

TABLE 4

CORRELATION MATRIX OF SUBJECTS' C-D PACE (\bar{X} MPH FOR 30 MIN) FOR THE 3 TESTING DAYS. GROUP I.

	Day 2	Day 3
Day 1	.61	.67*
Day 2		.92**

* $P < 0.05$; $r > .666$

** $P < 0.01$; $r > .798$

TABLE 5

CORRELATION MATRIX OF SUBJECTS' C-D PACE (\bar{X} MPH FOR 30 MIN) FOR THE 3 TESTING DAYS. GROUP II.

	Day 2	Day 3
Day 1	.51	.14
Day 2		.90*

* $P < 0.01$; $r > .765$

Inspection of Figure 2 reveals that on Day 1 Ss' performance was more variable as compared to Days 2 and 3 which accounts for the lower Day 1 vs. Day 2 and Day 1 vs. Day 3 correlations for Group II as compared to Group I.

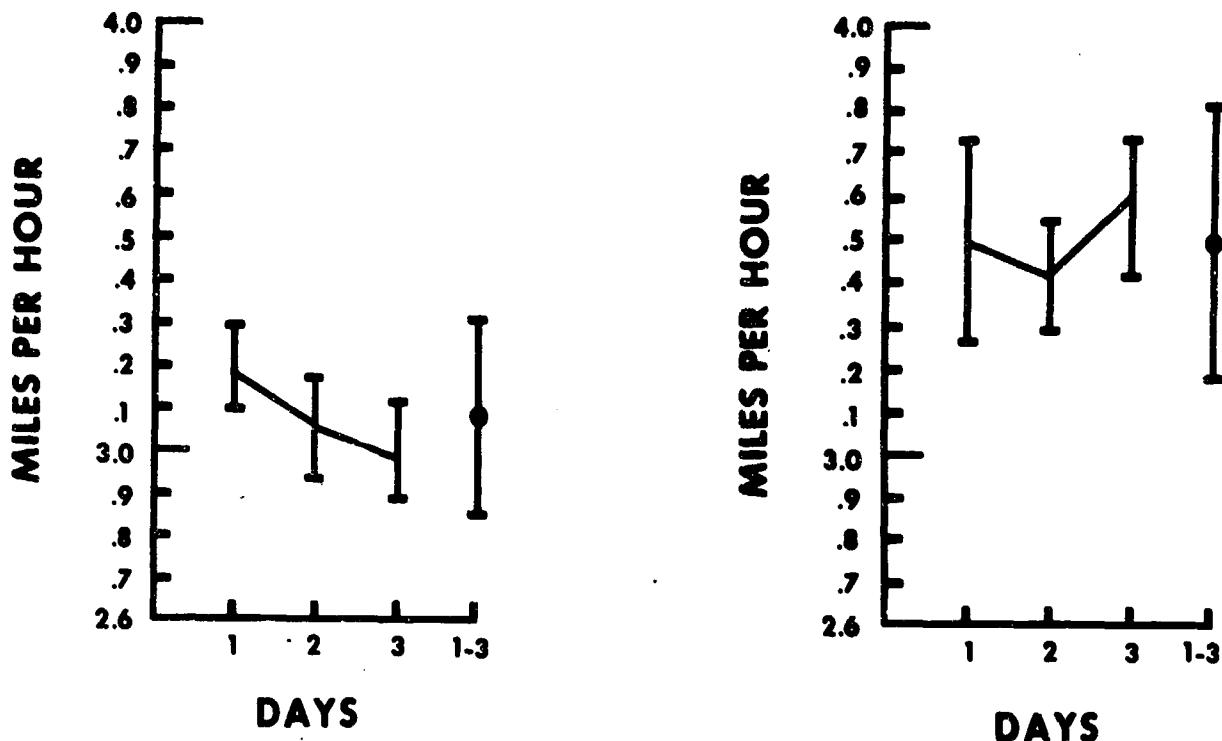


Fig. 2. Mean and standard deviation of 30 min walk for the 3 testing days. Groups I and II.

Because the correlations between Days 2 and 3 were so large, .92 and .90 respectively, analyses of variance were computed for both groups using only Days 2 and 3 to insure that performance in Day 1 was not primarily responsible for the significant days by Ss interaction obtained with the data for all three days. It was found that the days by Ss interaction, with Day 1 omitted, was still significant for both groups ($P < 0.001$) even though the magnitude of the F ratio was reduced.

Ss' performance on Days 2 and 3 are presented graphically in Figures 3 and 4 for Groups I and II respectively. Visual inspection of these graphs indicates that the primary reason for the statistically significant differences obtained between Days 2 and 3 is that variability of the C-D pace is so small. Thus, with very low variability even small differences between mean C-D pace levels on Days 2 and 3 are found to be statistically significant. For the majority of the Ss in both groups, the C-D pace on Day 2 was essentially the same as Day 3.

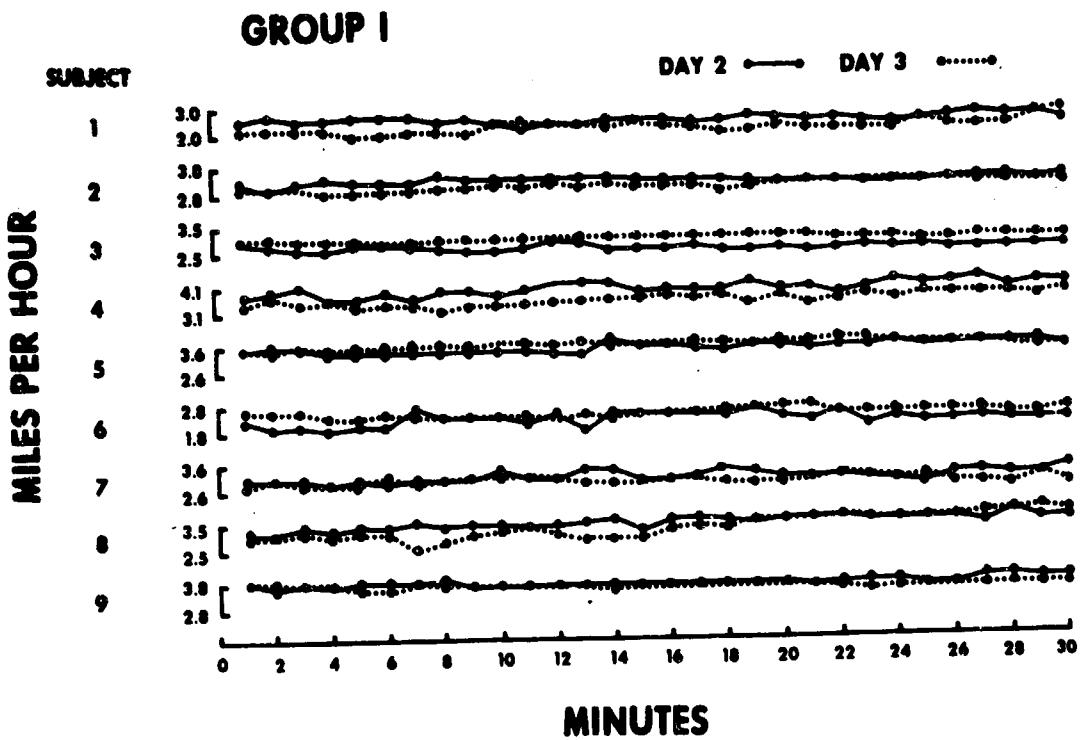


Fig. 3. Mean mph/min for the 30 min characteristic C-D walk on Days 2 and 3. Group I.

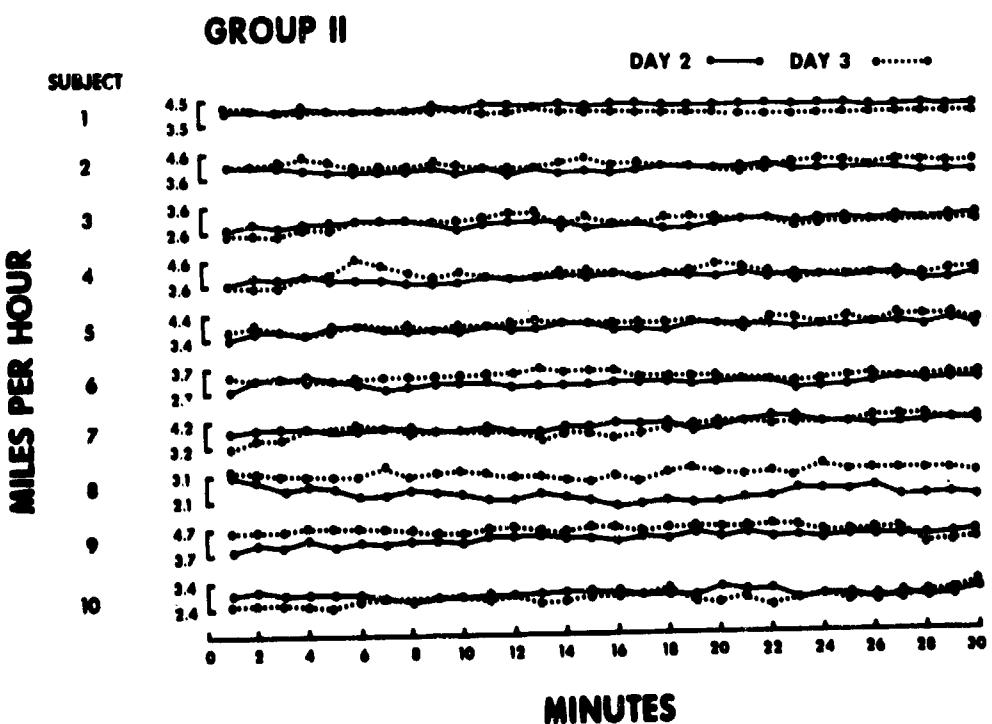


Fig. 4. Mean mph/min for the 30 min characteristic C-D walk on Days 2 and 3. Group II.

These results reveal that even though Ss' C-D pace on Day 2 may be significantly different statistically from their C-D pace on Day 3 (the significant days by Ss interaction), the C-D pace on Day 2 is highly similar to the C-D pace on Day 3 (the significant coefficients of correlation).

The discrepancy between the two S groups relative to the correlation of C-D pace between Days 1 and 3 combined with the observation that the over-all mean C-D pace for Group I was almost .5 mph lower than Group II suggests that in measures of this type of performance, large groups of Ss are to be desired. It is doubtful that the longer pre-C-D pace walks for Group II (8 min for each the slow to C-D and the fast to C-D walk for Group II as compared to 4 min for each of the pre-C-D walks for Group I) account for the difference observed. One difference between the two groups of Ss that should be noted is that most of the Ss in Group I were going next to paratrooper training whereas none of the Ss in Group II were scheduled for this training. The extent to which this factor along with other factors (psychological and physiological) were related to differences observed will be the subject of future research.

The next step in this line of research is to determine the effect of initiating a walk with a fast pace (5 mph) vs. a slow starting pace (2 mph) in terms of the C-D pace the Ss attain. Based on observations made during the current research it is hypothesized that only 5 to 10 min are required after initiating a walk, either fast or slow, for an S to reach his daily characteristic C-D pace.

As the hypothesis that individuals have a characteristic C-D pace that is relatively stable on any given day was supported, it will not be possible to apply the relative loading technique to this dynamic muscle group activity to obtain various measures of endurance. It is hypothesized that of the various possible pace rates or walking measures to be related to various physical, physiological, or psychological measures available, two will be found to be the most meaningful in future research: (1) the Ss' variance of the C-D pace on any given day; and (2) the variance of the Ss' C-D pace from day to day.

SUMMARY

The present research was conducted for the purpose of determining the feasibility of applying the relative or proportional loading technique to the dynamic muscle group responses involved in walking for the study of various measures of strength and endurance. Application of relative-loading is dependent on whether or not individuals

exhibit a characteristic pace. Under a "comfortable-but-determined" (C-D) walking pace instructional set, two groups of Ss were tested for 30 min on each of three days. The treadmill (TM) employed was modified so that the TM "tracked" or followed the Ss' pace. Results of analyses of variance and product moment correlations of the C-D pace measures warrant the following results: (1) Ss exhibit a characteristic C-D pace that is fairly stable on any one testing day; (2) the Ss' C-D pace may vary at a statistically significant level from day to day; (3) the Ss' C-D pace is found to be the most reliable between the second and third day of walking.

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13. ABSTRACT It was found that when subjects walked on a tracking treadmill under a "comfortable-but-determined" (C-D) walking instructional set for a minimum of 30 min on each of three testing days: (1) subjects demonstrated a characteristic C-D pace that was stable on any given day; (2) subjects' C-D pace differed statistically from each other ($P < 0.001$); and (3) subjects' C-D pace measures were most reliable between testing days 2 and 3 ($P < 0.01$). (U)		

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